NTD Germanium Thermistor Production For Cuoricino and CUORE

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CUORE (Cryogenic Underground Observatory for Rare Events) is designed to be a large (750kg) array of 1000 TeO_2 crystals operated at 15° mK to search for rare events, particularly for the neutrinoless double beta decay of ^{128,130}Te. This experiment will succeed the MiBeta experiment, 20 crystals currently running, and the CUORICINO experiment, 56 crystals, currently scheduled. Research for CUORICINO and CUROE includes the production of larger crystals, reduction of natural radiation background, and the production of thermistors to read out the temperature rise in the crystals when an event occurs.

The thermistors currently used in MiBeta and those planned for CUORICINO and CUORE are produced by the neutron transmutation doping (NTD) of natural germanium. This involves subjecting Ge to a fluence of about 3 x 10^{18} neutrons/cm^2 in the core of the University of Missouri Research Reactor to produce doping levels of about 1 x 10^{17} Ga atoms per cm^3, 3 x 10^{16} As atoms per cm^3 and 2 x 10^{15} Se atoms per cm^3. The word “about” as used here is not to imply that a large variance is acceptable, in fact, very precise doping is required since the doping must bring the Ge very near to the insulator / metal transition. The word “about” indicates the uncertainty in reactor parameters that leads to different doping concentrations observed under identical “nominal” reactor conditions. Because of this, doping has typically been done in a two step process: The first irradiation delivers 90% of the calculated dose. After a year of decay time, the electrical properties of the Ge are measured, and the remaining irradiation time is calculated using nominal reactor parameters.

In an effort to better characterize the reactor parameters, we have sent Fe and Co monitors along with 6 sets of Ge samples, and used results from the two monitors to determine the thermal and epithermal neutron fluxes, and calculated the expected doping in the thermistors. Results indicate that this technique will allow precise reproducibility of thermistor material, perhaps to ±2.5%, assuming a two-step process. However, instead of having to wait a year after the first irradiation, results of the monitor foils can be used instead of electrical measurements, and thermistor production time can be reduced by approximately one year.

Mn and Rh monitors were also sent with the samples to measure the fast flux in the reactor. The activation of Mn with a Q-value of –10.2 MeV and Rh with a Q –value of –9.3 MeV can indicate production of ^{68}Ge, a 270 day half-life isotope observed in previously fabricated thermistors, and a problem because of its radioactivity and its long half life. Low activities of ^{54}Mn and ^{102}Rh, activation products from natural Mn and Rh, were observed, indicating the presence of neutrons with energies exceeding 10 MeV, and at least partially explaining the production of ^{68}Ge . We say “partially” since the Q-value for the production of ^{68}Ge via the (n,3n) reaction is –22 MeV. ^{68}Ge could conceivably be produced in a two-step process involving two reactions with Q-values in the range of –10 MeV.

Finally, the NTD Ge itself was examined. Besides the dominant structure indicative of the inner bremstrallung from the 11 day half-life decay of ^{71}Ge, a variety of impurity activities were observed including ^{68}Ge , ^{65}Zn , and ^{75}Se.

Two major results come form this work. 1) Using a simple set of monitor foils, we expect to be able to dope the germanium reproducibly to ±2.5% and 2) we need to study other irradiation sites in the reactor to see if we can eliminate more of the higher energy neutrons.

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